C H A P T E R - IV

A PURIFIED DIET AND A PRACTICAL FEED FOR PRAWNS

INTRODUCTION

Compounded diets can be classified as purified diets and practical feeds. The former diets are formulated using purified ingredients and are generally used for studying the nutritional requirements of the animals, whereas the practical feeds are formulated based on the nutritional requirements of the recipient animal, using naturally available feed materials and are used for different phases of culturing the animals. Different purified diets, for standard reference, have been published in literature for finfish (Halver, 1972), Prawns (Kanazawa et al., 1977a) and lobsters (Conklin et al., 1980; Boghen et al., 1982; Kean et al., 1985). Any one of these diets could be used for nutritional studies in finfish and shellfish. But very often, it happens that these diets could not be formulated in totality in a given region as some of the diet components enlisted may not be available in that particular region. This situation necessitates the development of a purified diet formulated using the ingredients locally available and suitable for the species that are cultured in the prevailing conditions of the region.

In the traditional prawn and fish culture practices in the brackishwater region followed in India and some of the south-east Asian countries, feeding of the population in the pond is generally not practised. The prawn and fish population grow by feeding on the natural food available in these ponds. Supplementary feeding is resorted to only when the productivity or the growth of the natural food in the pond is found depleted. In such cases and in the early years of development of semi-intensive culture systems, several kinds of supplementary feeds have been used with varying degrees of success. The most important supplementary feeds used are clams, mussels, trash (cheaper varieties) fish, animal flesh, oil cakes such as groundnut, coconut, gingelly, mustard and soybean; rice bran, wheat bran, and other grains either singly or in combinations.

With the rapid progress of semi-intensive and intensive systems of culture, the formulation and development of practical feeds, meeting the nutritional requirements of candidate species for obtaining optimum growth and survival during the different phases of its growth and in consideration of the cost of manufacture of feed, have been assigned high priority. Accordingly, during the past two decades, considerable advancements have been made in the various aspects of feed development and feed technology. As a result of the Research and Development Programmes, several types of compounded feeds are developed and being used for the culture of prawns in different regions. (Asia: Hirasava, 1984; Kungvankij, 1984;. Japan: Shigueno, 1984; Philippines: SEAFDEC, 1981, 1983; Liu and Mancebo, 1983; Apud, 1984; Pascual, 1984; Tibbu et al., 1984; Taiwan: Liao, 1981; Chiang and Liao, 1985; Tahiti: AQUACOP, 1984a,b; United States: Caillouet et al., 1974; Parker and Fred, 1974; Elam and Green, 1974; Huang et al., 1984; Lee and Shlesser, 1984; Latin America: Escobar, 1984; Scura, 1985).

In India attempts were made to develop the practical feeds with the locally available materials by Alikunhi et al. (1980), Ahamad Ali and Sivadas (1983) and Mohamed et al.(1983) to rear the larvae in the hatchery and post larvae in the nursery. With a view to developing suitable artificial feed for feeding the prawns in the grow-out systems, different types of feeds were formulated and feeding experiments were conducted by many workers (AICRIP, 1978; Ahamad Ali, 1982a; Mohammed Sultan et al., 1982; Raman et al., 1982; Ahamad Ali and Mohamed, 1985.) Recently a pelletized feed under the brand name 'Tamco feed' has been introduced by M/S. TATA, Madras and it was supplied to the farmers at a subsidised price by Marine Products Export Development Authority.

Although the above endeavours have provided certain information on the use of the compounded feeds, the results and the Production rate obtained have been inconsistant and it is found imperative that an appropriate formulated feed has to be further developed and perfected for large scale use in the commercial operations. In this context, on the basis of results obtained in the present study, a purified diet is formulated with the intention that this formula diet can be used as a basal purified diet for studying the nutrition of penaeid prawns in this region, as all the diet components listed in the diet are easily available. A practical feed is formulated using feed ingredients evaluated in the present study and attempts are made to balance it according to the requirements of the prawn *P. indicus*. Long term feeding experiments are conducted in the laboratory with the purified diet and the practical feed formulated on *P. indicus*. The results are compared with those of the conventionally used feed fresh clam meat. The prospects of using the purified diet for nutritional studies in this region and the practical feed for the culture of penaeid prawns are discussed.

MATERIAL AND METHODS

The ingredients, albumen (egg), sucrose, maltose, starch, cod liver oil, used for preparing purified diet, and prawn waste, mantis shrimp, fish meal, groundnut cake and tapioca, used for preparing practical feed are already described in Chapter I.

Formulation of diet and feed

Purified diet: The purified diet, designated as PDP, was formulated using albumen (egg) as the protein source, a mixture of sucrose, maltose, starch (in equal proportion), as carbohydrate source and cod liver oil, as the source of lipid. Cholesterol, glucosamine and the vitamin mixture were added based on the purified diet formulated by Kanazawa *et al.* (1970) for *P. japonicus* The mineral mixture consisted of calcium carbonate, potassium dihydrogen orthophosphate, copper sulphate and zinc chloride, prepared according to the requirement of these minerals shown by *P. indicus* in the present study. The diet had 28.9% crude protein, 40% mixed carbohydrate and 6.17% of cellulose which were found to be adequate for this prawn. Sodium alginate was used as the binder. The composition of the diet is given in Table 60.

Practical Feed: The practical feed, designated as PFP, was formulated using prawn waste, mantis shrimp, fish meal, groundnut cake and tapioca. The protein base in the feed was made up of 65% of animal protein source and 35% plant protein source. Tapioca was used as the source of carbohydrate. A commercial vitamin mixture (Becadex) manufactured by Glaxo Laboratories, Bombay and meant for human consumption, was included in the feed. Since the feed had adequate levels of calcium and phosphorous,

Table 60. Composition (g/100g) of purified diet -PDP

Ingredients	g/100g.
Albumen (egg)	35
Carbohydrate mix	40
Cod liver oil	6
Cholesterol	0.5
Glucosamine HCl	0.8
Vitamin mixture 1	2.7
Mineral mixture 2	5.83
Cellulose	6.17
Sodium alginate	3.00
Crude protein (%)	28.90

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1. Vitamin mixture: Same as used for the diets PE_0 to PE_4 in Chapter I (Table 2a)

2. Mineral Mixture:

Calcium carbonate	=	1.3
Potassium dihydrogen orthophosphate	=	4.4
Copper Sulphate	=	0.06
Zinc chloride	=	0.07
		5.83

these were not added, but copper and zinc were supplemented at the required level in the feed. Since tapioca acts as the binder, no additional binder was used. The composition of the feed is given in Table 61.

Control feed: The fresh meat of the clam, Sunneta scripta was used as the control feed. The composition of the clam meat was same as given in Chapter I (Table 2).

Preparation of purified diet and practical feed: The method of preparation of purified diet and the practical feed is same as described under the respective sections in Chapter I.

Feeding experiments: Hatchery reared, early juveniles of the prawn Penaeus indicus with an average length of 20.7 mm and average live-weight of 0.0249g were used in the feeding experiments. The animals were stocked in 3' x 2' circular plastic pools (Plate 4), containing 200 L of a mixture of filtered sea water and tap water to give a salinity of about 16‰. Each pool had ten animals and there were three replicates for each treatment. The water in the pools was completely replaced once in five days and aeration was provided with the help of an air compressor. The hydrographical data is presented in Table H_4.

The animals were fed at 20% of the body weight approximately in two devided doses in the morning and evening. Feed was placed in petridishes kept in the pools. Left over feed was removed, washed gently with water and dried in the oven at 60° for 12 hrs. The feeding experiment was continued for a period of 100 days.

The total length and live-weight were measured before and after feeding experiment individually for each treatment.

Table 61. Composition of practical feed - PFP

Ingredients	(g)
Prawn waste	14.0
Mantis shrimp	14.0
Fish meal	11.0
Groundnut cake	21.0
Tapioca	40.0
Vitamin mixture[1]	1.0
$CuSO_4$	0.06
$Zncl_2$	0.07

Proximate composition	(g/100g)
Moisture	5.60
Crude protein	28.02
Lipid	10.00
Carbohydrate	34.40
Ash	16.80
Crude fibre	5.18
Calcium	2.54
Phosphorous	1.23

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1. Vitamin mixture (1 g consists of)

Vitamin A	5000 I.U.
Vitamin D_3	400 I.U.
Vitamin B_1	4 mg
Vitamin B_2	4 mg
Nicotinamide	50 mg
Vitamin C	60 mg
Calcium phosphate	500 mg.

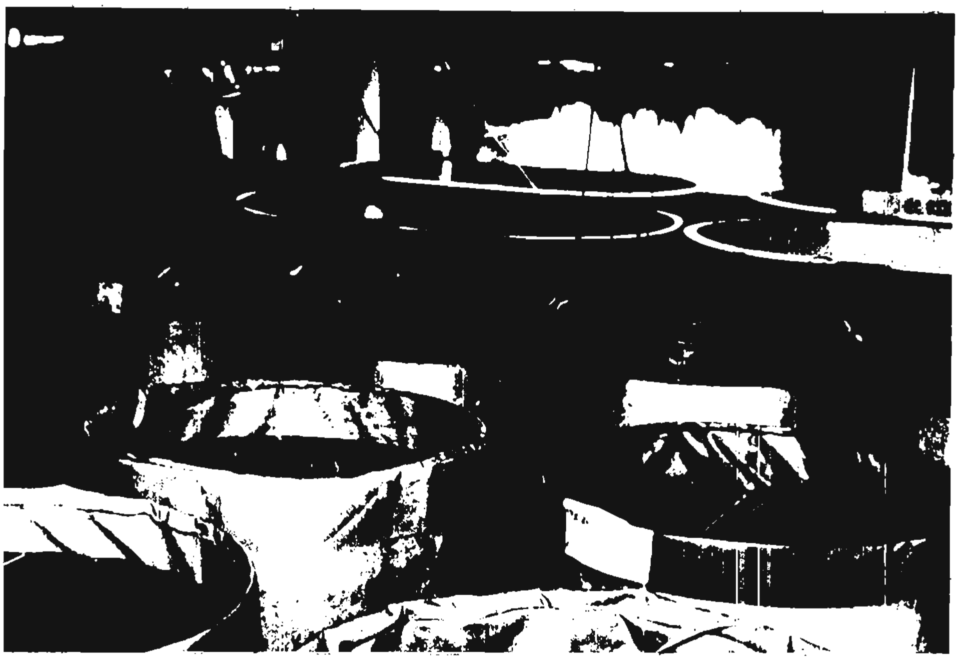

Plate 4. Plastic liner pools used for long term feeding experiments with purified diet (PDP), practical feed (PFP) and fresh clam meat.

Table H_4. Hydrographical data of the feeding experiment with PDP, PFP and clam meat.

Salinity ‰	Oxygen CC/L	Temperature °C	pH
21.2 - 25.9	3.81 - 4.21	28.4 - 30.2	8.1 - 8.29

Biochemical Analysis: The preparation of samples of animals and the diets for analysis and the methods used for analysing them for protein, lipid, carbohydrate and ash are the same as described in Chapter I. Moisture was estimated by drying the sample at 60°C to constant weight. While calcium and phosphorous were estimated by the same methods described in Chapter III, crude fibre was determined by the AOAC method.

Statistical Analysis: The data obtained by the purified diet, practical feed and the control feed on growth and food conversion ratio were subjected to analysis of variance and the results are shown in Table 62 A.

RESULTS

The results of the feeding experiment conducted with PDP, PFP and fresh clam meat are presented in Table 62. The practical feed PFP produced highest increase in length (72.2mm) and live weight (4.69g), followed by the fresh clam meat(63.7mm in length and 4.42g in live-weight) and the purified diet(54.7mm in length and 3.83g in live-weight). The increase in length and live-weight obtained by the practical feed and clam meat were significantly higher ($P < 0.05$) than the increase in length and weight obtained by the purified diet. However, the difference in length and weight obtained by the practical feed and fresh clam meat was not significant. The food conversion ratio (FCR) obtained by the practical feed was the lowest (1.80) followed by the clam meat (2.09) and purified diet (2.37), though the values were not statistically different ($P \angle 0.05$). The survival of the animals was the highest in the case of purified diet (90%), followed by the practical feed (63.3%) and clam meat (53.0%).

The crude protein in the animals fed the practical feed, PFP was the highest (66.53%) while the animals fed the clam meat had low protein (60.4%). However, the lipid of the animals fed clam meat had shown high value (21.0%) and that of the animals fed practical feed was low (13.6%). The carbohydrate and ash did not differ significantly among the animals fed the different feeds.

The growth curves of the animals fed the three different feeds are shown in Fig. 41. For the first ten days, the increase in live weight (Fig.41a) and length (Fig.41b) was similar

Table 62. Results of the feeding experiment conducted with PDP, PFP and fresh clam meat on *P. indicus* for 100 days.

Particulars	Feed		
	PDP	PFP	Fresh clam meat
Initial average length(mm)	20.9	20.7	20.8
Initial average live-weight (g)	0.0249	0.0249	0.0249
Final average length(mm)	75.5	92.9	88.1
Final average live-weight (g)	3.86	4.72	4.45
Increase in length (mm)	54.7[c]	72.2[a]	63.7[b]
Increase in live-weight(g)	3.83[b]	4.69[a]	4.42[a]
Food conversion ratio	2.37	1.80	2.09
Survival %	90.0	63.3	53.0
Composition of animals (% on dry basis) after completion of feeding experiment.			
Crude protein	63.90	66.53	60.40
Lipid	18.60	13.60	21.00
Carbohydrate	1.41	1.44	1.52
Ash	17.23	16.93	16.81

Note: Values with different superscripts differ significantly among themselves. Increase in length and weight significant at 5% level ($P < 0.05$). Food conversion ratio not significant at 5% level ($P < 0.05$).

Table 62 A. Analysis of variance of the data obtained by PDP, PFP and fresh clam meat

Source	D.F.	S.S.	M.S.
		ANOVA	
1. Increase in length			
Treatment	2	588.15	294.07*
Error	6	52.93	8.82
Total	8	441.08	302.89
2. Increase in live-weight			
Treatment	2	1.18	0.59*
Error	6	0.19	0.03
Total	8	1.37	0.62
3. Food conversion ratio			
Treatment	2	0.495	0.2475[N]
Error	6	1.50	0.2500
Total	8	1.995	0.4975

* Significant at 5% level (P ∠ 0.05)
N Not significant (P ∠ 0.05)

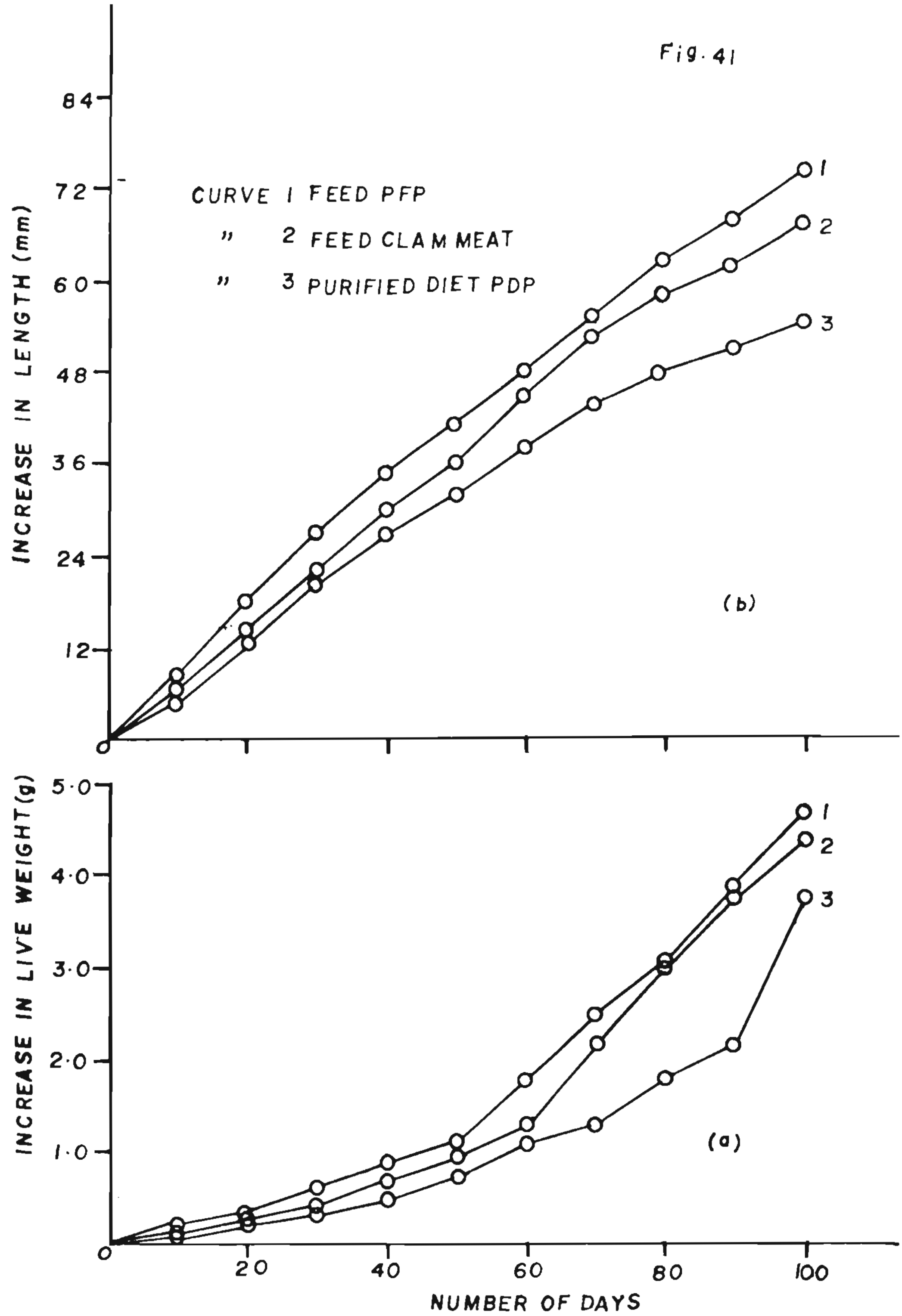

Figure 41. Growth curves (a) weight and (b) length of P. indicus fed with purified diet (PDP), Practical feed (PFP) and fresh clam meat.

in the case of all the three feeds. With time, the growth curves separated out, with the practical feed PFP occupying the top position and the purified diet PDP, occupying the lower position. The control feed clam meat remained intermediate between the practical feed and purified diet.

DISCUSSION

The purified diet PDP, formulated with albumen (egg), mixed carbohydrate, cod liver oil, vitamins, minerals and other additives resulted in the highest survival (90%) of the prawn *Penaeus indicus* at the end of 100 days rearing. The average increase in length of the animals fed this diet was 54.7mm and the average increase in weight was 3.83g. The food conversion ratio of the diet was 2.37. Purified diets were first formulated by Kanazawa *et al.* (1970) for the prawn *P. japonicus* and subsequently by Kitabhayashi *et al.* (1971a, b, c, d) and Deshimaru and Kuroki (1974a,b,c, 1975a, b) for studying different aspects of nutrition. AQUACOP (1978) and Kanazawa *et al.* (1981) formulated purified diets for studying the nutritional requirements of *P. merguiensis*. Lim *et al.* (1978) prepared casein diets and compared with those of shrimp meal, squid meal and *Spirulina* for the post larvae of *P. monodon*. Ahamad Ali (1982b), Charles John Bhasker and Ahamad Ali (1984) and Gopal (1986) prepared purified diets for the prawn *P. indicus* to study carbohydrate and protein requirements in the diet. Alava and Pascual (1987) formulated and prepared purified diets for *P. monodon*. While Conklin *et al.* (1980) evolved a purified diet for the culture of juveniles of American lobster *Homarus americanus*, D' Abramo *et al.* (1981, 1982, 1984) studied the requirements of different nutrients for the same lobster using purified diets. In all the above mentioned works, casein was used as the protein source whereas albumen (egg) was used in the purified diet PDP in the present study. Most of the diets formulated in these studies were test diets and the protein content varied from 15 to 80% where as the protein content of the purified diet PDP was only 28.9%.

The growth obtained by the purified diet PDP in juvenile P. indicus compares well with growth of P. japonicus obtained by Kanazawa et al.(1970), P. merguiensis by AQUACOP (1978) and Kanazawa et al. (1981) and of P. monodon reported by Lim et al. (1978) and Alava and Pascual (1987). The growth of the prawns obtained in the present study is higher than the growth recorded in P. indicus fed with casein diets by Ahamad Ali (1982b) and Charles John Bhasker and Ahamad Ali (1984). Besides, the food conversion ratio and the survival rate obtained by the present diet in P. indicus are superior to those obtained in P. japonicus P. merguiensis and P. monodon in the studies mentioned earlier. These indicate that the purified diet PDP, prepared with albumen is superior to the casein diets.

However, the growth and food conversion ratio shown by the diet PDP are lower than the growth and food conversion ratio recorded by the Practical feed PFP and also the control feed clam meat in this study. Only the survival of the animals fed with the purified diet was higher as compared to those fed with the control feed and the practical feed. But such inferior growth of prawns fed with the synthetic purified diets is not uncommon in nutritional studies. Poor growth of prawns, fed with purified diets prepared with casein, gelatin, albumen and amino acid mixtures, compared to the diets prepared with natural ingredients, was reported by Sick et al. (1972), Deshimaru and Kuroki (1974c, 1975a, 1975b), Ahamad Ali (1982b) and Teshima et al. (1986e). The difference in the growth of the prawns fed with purified diet and natural feed might be due to the non-palatability of the purified diet as it is prepared with purified materials and chemicals. Nevertheless, the use of purified diets is essential as the effect of a particular nutrient could be clearly understood, without the interference of extraneous factors, only through purified ingredients.

It is well known that purified diets are primarily meant for studying the nutritional requirements of candidate species. However, these are also used for practical purposes, Villegas and Kanazawa (1980) and Jones et al. (1979a) used the purified diet for rearing the larvae of P. japonicus, and Conklin et al. (1980) for culturing the juveniles of the lobster, Homarus americanus. Some of the purified proteins are also mixed with natural ingredients in formulating diets (Lee, 1971; Andrews and Sick, 1972; Alava and Lim, 1983) either to enhance the protein level of the diet or to balance the aminoacid profile. A balanced purified diet can be used for maintaining animals in laboratory where practical feeds are not available. Feed attractants such as Squid extract, mussel mantle, shrimp extract and aminoacids like glutamic acid are often used in purified diets to increase their acceptability.

Feeding constitutes a major cost of aquaculture production. It is thought that the triumph of future aquaculture depends largely on the development of a nutritionally balanced and economical feed and its sustained supply. In this context, the results of the experiments conducted on the practical feeds in this study are compared with those similar observations and discussed.
The control feed fresh clam meat produced low growth and survival compared to the practical feed in the present study. Similar results were reported in P. indicus with fresh clam meat by

Colvin (1976a) and Ahamad Ali (1982a), especially it resulted in high mortality in both the studies. Ahamad Ali (1982a) observed frequent moulting and high incidence of cannibalism in the prawns fed with fresh clam meat. Contrary to the results obtained in P. indicus, Kanazawa et al. (1970) reported superior growth in P. japonicus fed with the meat of short-necked clam (Tapes philippinarum). Similar observations were made by Forster and Beard (1973) in the Prawn Palaemon serratus. However, clam meat by itself may not be considered as a nutritiously balanced feed for prawns. Besides, it is relatively expensive (5 to 8 rupees per kilogram of fresh meat with 80% moisture) and is used for human consumption. Further, the availability of clam meat in adequate quantity for feeding large scale culture of prawns may not be assured. It may, however, be used as supplementary feed for prawns wherever it is available at a competitive price.

The practical feed PFP prepared with prawn waste, mantis shrimp, fish meal, groundnut cake and tapioca, fortified with vitamins and minerals gave highest growth (72.2mm in length and 4.69 g in weight) and best food conversion ratio (1.80) in P. indicus among the three diets tested. The survival of the prawns fed with the practical feed was 63.3%.

Several different feeds were formulated in India for feeding the prawns. At the Kakdwip Research Centre (AICRIP 1978), supplementary feeds were formulated, consisting of soybean flour, brewer's yeast, maize powder, wheat flour, calcium phosphate, vitamins and algin, for feeding the post larvae of P. monodon, and another feed consisting of goat offal, yeast, algal powder, wheat flour and terramycin for feeding the post larvae of P.

<u>indicus</u>. It was reported that the survival of the post larvae fed with the above feeds, ranged between 57% and 90% depending upon the temperature of the medium. In another experiment, four feeds were prepared with prawn meal alone, prawn meal + maize (1:1), prawn meal + Wheat powder (1:1) and wheat powder and maize (1:1) and fed to the post larvae of <u>P. monodon</u> at different feeding rates. It was found that the feed with prawn meal + wheat powder (1:1) gave the highest survival of 90% at 10% (of body weight) feeding level at the end of 8 weeks. The survival of <u>P. indicus</u> in the present study is 63.3% which is slightly less than that recorded in <u>P. monodon</u> post larvae in the above study.

At the Kakinada Brackishwater Research Centre(AICRIP, 1978), feeding trials were also conducted on <u>P. monodon</u> in cement cysterns with three feeds prepared with a mixture of fish meal, groundnut cake and rice bran, fish meal alone, and flesh of trashfish (<u>Oryzias melastigme</u>). It was reported that the feed prepared with flesh of trashfish gave the highest growth and best food conversion ratio (FCR). The post larvae of <u>P. monodon</u> fed with the feed mixture had grown from 0.015 g to 0.332 g on an average in 30 days, where as those fed with fish meal alone had grown from 0.015g to 0.2415g and those fed with trashfish, from 0.015g to 0.368g. The FCR recorded by the feed mixture was 3.5, while those recorded by the fish meal and trashfish were 4.37 and 1.26 respectively. In the present study, <u>P. indicus</u> fed with the practical feed had grown from 0.0249g to 4.72 g in 100 days. While the FCR (1.80) of the practical feed prepared in present study is slightly inferior compared with the FCR of flesh of trashfish obtained in *P. monodon*, it is superior to the FCRs recorded by the feed mixture and fish meal.

Raman *et al.* (1982)conducted feeding trials on *P. indicus* using different combinations of feed ingredients consisting of fish meal, prawn factory waste, groundnut oil cake, gingelly cake, black gram husk, Bengal gram husk, bajra, wheat flower, wheat bran, rice bran and tapioca. Among the feed combinations tested, fish meal, rice bran and tapioca in the ratio 1:1:1 and 2:2:1 gave satisfactory results. The FCR obtained by the first combination feed was 1.69, while it was 3.21 and 3.32 by the second combination feed in two different experiments. The FCR (1.80) of the practical feed PFP for *P. indicus* compares well with the FCR obtained by the first combination but superior to the FCRs of the second combination feed reported by Raman *et al.* (1982). Mohammed Sultan *et al.* (1982) formulated feeds with frog flesh waste and reported a food conversion ratio between 3.01 and 4.96 for *P. indicus* and 5.87 and 8.21 for *P. monodon*. The food conversion ratio obtained by the feed in the present study is superior to FCRs obtained by the feeds with frog flesh both in *P. indicus* and *P. monodon* in the above study. Compounded feeds were formulated using prawn waste, mantis shrimp, groundnut cake and tapioca for feeding juveniles of *P. indicus* by Ahamad Ali and Mohamed (1985) and the best feed among the tested, recorded a food conversion ratio of 3.22. Compared to this FCR, the FCR obtained (1.80) in *P. indicus* is superior in the present study.

Out side India, Colvin (1976a) studied the growth, digestibility and FCR of some diets formulated with fish meal and shrimp meal in *P. indicus* and reported a growth of about 44 mg/

day and the lowest FCR of 2.72. While the growth of P. indicus in present study is 46.9 mg/day, the FCR is 1.80 which are superior to those reported by Colvin (1976a). Recently Apud et al. (1984) studied the growth, survival and production of the prawn P. indicus in brackishwater ponds in the Philippines. Supplementary feeding of the prawns was done with a compounded feed. The production was 343.2 Kg/ha in the test pond (where feeding was done) and 180 Kg/ha in the control pond. The average survival was 70.36%. The FCR of the feed was not reported for comparison with that of the present practical feed.

The performance of the present practical feed compares well with some of the diets formulated for other species. Feeding trials conducted on P. monodon cultured in cages using a practical feed in the Philippines (SEAFDEC, 1981) had shown a food conversion ratio of 4.8. In a semi-intensive culture experiment with the same prawn (SEAFDEC, 1983), a commercial prawn feed with 45% protein and an experimental feed with 35% Protein produced FCRs 3.4 to 4.6 and 6.1 respectively. Similarly in another intensive culture experiment (SEAFDEC, 1983), a crustacean pelleted feed resulted in a FCR of 3.01 in the same prawn. Certainly, the FCR (1.80) shown by the practical feed in P. indicus in the present study is much lower than the FCRs obtained by the feeds tested in P. monodon in the above experiments. Further, in pond culture experiments with P. monodon in the Philippines, Liu and Mancebo (1983) used a commercial formula feed developed by the 'President Enterprises Corporation', Taiwan, and obtained food conversion ratios of 1.69 and 1.78. The FCR of the present practical feed in P. indicus is in agreement with these values.

Venkataramaiah et al. (1972a,b, 1975a,b), while studying the effect of feeding level and salinity on growth and FCR in P. aztecus, reported that the FCR of a standard prawn feed varied from 3.73 to 1.25, and the FCR of the present practical feed (1.80) in P. indicus falls within this range. But the FCR of the diets formulated with fish meal, having different protein levels, in P. aztecus (Venkataramaiah et al., 1975a) ranged from 2.8 to 19.0 which are inferior to the FCR obtained by the feed in the present study.

Elam and Green (1974) conducted feeding experiments with different formula feeds on P. setiferus and obtained food conversion ratios ranging from 1.8 to 2.3 which are comparable to the value recorded by the feed in the present study. However, the pink shrimp P. duorarum fed with wheat bran and a catfish ration attained 6.0 g and 8.0 g weight in 78 and 92 days respectively, in pond experiments (Caillout et al., 1974). Parker and Fred (1974), while studying the shrimp production module for P. aztecus observed that the Prawns fed standard commercial rations attained a weight of 10.77 g in 139 days, while P. stylirostris attained a weight of 6.54 g in 136 days. Compared to the size of the prawns attained in above studies, the weight attained by P. indicus in present study is low. But these differences are obvious because of the species difference and also the difference in experimental conditions in these investigations.

From the above discussions it is clear that the performance of the present practical feed PFP is componable to that of many of the standard formula feeds used for feeding penaeid prawns and it is superior to the performance of some of the formulated feeds.

Moreover, the material cost of the present practical feed is found to be Rs. 3/- per kilogram, based on the existing retail prices of the ingredients (prawn waste Rs. 2/-per kg; mantis shrimp Rs. 2/- per kg; Fish meal Rs. 6/- per kg; tapioca Rs. 2/- per kg) including the cost of vitamin and mineral mixture (which is equivalent to Rs. 0.35 per kg of the feed). With a food conversion ratio of 1.8, the cost of the feed to produce one kilogram of prawns is only Rs. 5.40 which can be considered as very economical.

Prawn waste and mantis shrimp are available in sufficiently large quantities in most of the maritime states. A major portion of these two materials is not utilised at present and are practically thrown away. Only a small quantity of prawn waste and mantis shrimp are collected, sun dried and used as manure or mixed with some plant fertilizer mixtures and in poultry feeds. Nevertheless, these two materials are potential feed ingredients to reckon with for formulating prawn feeds. Both prawn waste and mantis shrimp are good sources of animal protein rich in essential amino acids (Forster, 1975; Sandifer and Joseph, 1976) and have shown good digestibility and biological value (Chapter I) Besides, prawn waste is a good source of lipid rich in poly - unsaturated fatty acids and carotenoids (Joseph and Meyers, 1975; Joseph and Williams 1975; Ahamad Ali, unpublished) essential for prawns. It also contains calcium and phosphorous and the Chitin present in it has growth promoting effect (Vaitheeswaran and Ahamad Ali, 1986) when mixed with the diet of _P. indicus_. The composition of prawn waste sometimes varies according to the size of the prawns from which it is derived. Often it was found that the residual meat was left more in the peelings of smaller size prawns such as *Metapenaeus dobsoni*, *M. monoceros* and *Parapenaeopsis stylifera*, compared to the larger prawns such as *P. indicus* and *P. monodon*. In the case of mantis shrimp large size animals (contain higher amount of meat) are landed generally from December to May. In other months, the landings of mantis shrimp are very less and also the size of the animals is very small. The composition of mantis shrimp meal is very much influenced by the presence of trashfish, molluscs, crabs, starfish and other biomass, which are generally discorded along with this material.

Fish meal, though available in fairly large quantities at present, it is in great demand as a feed ingredient of other animals, especially poultry. Of late the production of fish meal is on the decline in the country. As a potential raw material for prawn feeds, fish meal production should be encouraged for the development of large scale prawn farming in the years to come.

Fish meal is a good source of protein with essential amino acids and has high biological value. The composition and quality of fish meal varies according to the rawmaterial used for preparing it. Generally fish meal with a protein content of above 60% is considered as good quality fish meal. White fish meal prepared using predominantly silver belleis and anchovies are of high quality compared to the brown fish meal prepared using sardines and other trashfish.

Groundnut cake, which is a versatile feed ingredient of many animals, is available in fairly large quantities. It is a good source of plant protein. The composition of groundnut cake is known to vary according to the process used for expelling the oil. The cake obtained from mechanical expellers contains higher amount of lipid than that obtained from the solvent extraction process. Seasonal and regional variations are known to cause minor differences in the composition of groundnut cake.

Tapioca is a double action material in prawn feeds. It is a very good source of carbohydrate and at the same time acts as the natural binding agent in aquatic feeds. The water stability of feed pellets prepared with tapioca as binder was tested (Ahamad Ali, 1986) and found that the Pellets prepared with 20% of it were stable for more than 6 hours in the water. Its binding capacity was comparable to chemical binders such as agar agar, sodium alginate and polyvinyl alcohol. Tapioca is available in large quantities in Kerala, Tamil Nadu and Andhra Pradesh.

Taking into account, the good performance of the feed, its low cost, the adequate availability of ingredients, the detailed information available on the techniques of preparation of water stable pellets, the practical feed PFP can be recommended for the large scale culture of the prawn *Penaeus indicus*.

GENERAL REMARKS

On a perusal of the available information at present, the live feeds, especially, the diatoms seem to meet adequately the requirements for rearing the larvae of penaeid prawns. Mixed culture of phytoplankton are successfully used for rearing protozoea to post larvae. But after post larvae, diatoms alone are not adequate. Introduction of micro-particulate compounded feeds of different types, for rearing the post larvae both in hatchery and nursery until they become stockable size, has helped in largely replacing the use of live feeds such as Artemia, rotifers and other organisms. However, the success of using artificial feeds for rearing the early stages of larvae (Protozoea to Post larvae) is yet to take off on large scale. Eventhough it is possible to prepare a nutritionally balanced feed, the greatest impediment has been the physical design of the diet. The diet should have a particle size below 50 microns, having all the nutrient package in it and these particles should be kept in suspension in the water column without appreciable loss by leaching. Tissue suspensions (Alikunhi et al., 1980, 1982; Hameed Ali, and Dwivedi, 1982) and powdered formula feeds (Mohamed et al., 1983) were used for culture of larvae of penaeid prawns in out door tanks. In these systems, the excess feed helps in the growth of diatoms which are also consumed by the larvae. Nevertheless, it is reported that the technique works successfull resulting in good survival of post larvae comparable to the survival rates obtained in the conventional systems. It is emphasised that this mixed diet (artificial diet + diatoms grown in the culture tank) technique obviates seperate production of diatoms for this purpose. Further, the same artificial feed could be used for subsequent rearing of the post larvae in hatchery and also in the nursery. It may therefore, be worthwhile that investigations may be carriedout on the comparitive economics of this technique with that of the standard techniques.

In the recent past, considerable technological advancements have been made in the preperation of larval feeds through encapsulation and micro-binding. Reports of rearing the larvae using these diets in the hatchery are available (Kanazawa, 1985; Jones et al., 1987). However, further information on their large scale production and economic use are required before they could substitute the live feeds being used at present for rearing the larvae of prawns.

As juveniles and adult prawns are capable of holding the food and nibble on, pelleted feeds appear to be more appropriate than the soft moist feeds which appear to be more acceptable. Preparation and storage of dry pellets are more practicable. The performance of an aquatic feed depends upon many factors such as its nutritional balance, the ingredients used, the method of preparation and the abiotic properties. It is also important to adopt proper storage procedures of the feed to ensure its shelf life. Based on the requirements of receipient animal, the feed can be nutritionally balanced by the judicious selection of the ingredients. This could be more effectively achieved by formulating multi-ingredient formula feed rather than single ingredient feeds. If necessary, the feed can be fortified with vitamins and mineral mixtures to meet the requirement.

The range of feed ingredients used for formulating feeds are compiled in Table I. Certain feed stuffs, particularly of plant origin, are known to contain antinutritional factors which may inhibit growth of animals if not removed. Principal among these are soybean, which contains a digestive enzyme inhibiter (Urease), groundnut cake, containing phytates and cotton seed cake which contains gossypol. In addition, isothiocyanates and cyanogenic glycosides are found in linseed and hydrocyanic acid in tapioca. All these anti-nutritional factors are easily destroyed just by heat treatment of the material except the gossypol present in cottonseed cake which should be removed by a special process (Chow, 1978).

In a culture operation, since the cost of the feed constitutes the major expenditure,it should be kept at its minimum possible to make economically viable. But at the same time the nutritional quality of the feed cannot be compromised with. Selection of raw materials plays an important role in containing the cost of the feed. Materials which are used for human consumption should generally be avoided as it creates competition for them and escalates the cost. One of the important criterea for selection of feed ingredients is that they should be available in considerably large quantities with consistant quality.

Employing appropriate technique for preparing feed is essential to ensure its desired quality. Grinding feed ingredients to uniform particle size is imperative to prepare a homogeneous feed mixture. Non-uniformity of particles of ingredients not only results in poor quality of feed pellets but also leads to selective feeding by the animals disturbing the nutrition package of the feed. Grinding the materials into fine powder also helps in improving the digestibility and preparing compact and water stable feed pellets. It was reported that grinding the rawmaterials of feed to about 200 microns had resulted in highest water stability of the pellets, enhanced digestibility and best food conversion ratio (Rani, 1984) in the prawn Penaeus indicus.

As the feed has to be provided under the water column to the aquatic animals, its water stability plays a major role in its performance. Faster disintegration of the feed not only pollutes the culture medium but also leads to wastage of feed resulting in poor conversion ratio. Water stability of crustacean diets using different binding materials have been studied (Meyers et al., 1972; Meyers and Zein-Eldin, 1972; Balazs et al., 1973; Meyers and Brand, 1975; Meyers, 1980). Prominant binding materials used in the prawn feeds are agar agar, alginates (Sodium), gelatin, gums, carboxy methyl cellulose (CMC), Polyvinyl alcohol (PVA), Carrageanan (Polysaccheride), Zein (Corn protein) and starch. Selection of the binding agent has to be done carefully as some of the binders are very expensive and can considerably enhance the cost of the final feed. Natural feed materials such as wheat flour, wheat gluten, rice flour and tapioca are also used as binders besides being feed components. While tapioca, which contains more than 70% starch, is a good source of carbohydrate in the feed, it is also found to be a potential binding agent (Ahamad Ali, 1986) in prawn feeds. It was found that feed pellets prepared having 20% tapioca were stable under water for more than six hours. Its binding quality compared well with the binding quality of agar agar, sodium alginate and polyvinyl alcohol and was superior to that of pure starch.

Steaming the feed does many a good to it. It not only kills the unwanted micro-organisms and makes the feed inoccuous but also gelatinises the starch present in the feed and improves the digestibility and pellet stability. Steaming also removes some of the antinutritional factors present in certain feed materials. However, steaming the feed at higher temperature, especially under preseure, may bring in undesirable alterations in the feed ingredients and destroy some of the heat lebile components particularly, the vitamins. It is advisable to incorporate vitamins only after the steaming process is completed.

Proper storage of feed is as important as the development of a good feed. The lipid, particularly, the polyunsaturated fatty acids are very much prone to atmospheric oxidation leading to rancidity. The end products, epoxides and hydroperoxides are not only toxic to animals but also render some of the nutrients in the feed unavailable to the recipient animal. Eventhough the lipids contain the natural antioxidants, such as tocopherols, chemical antioxidants like Butylated Hydroxy Anisole (BHA), Butylated Hydroxy Toluene (BHT) and ethoxyquin are used to prevent the lipid oxidation.

Improper storage of feed may lead to insect attack, destruction by rodents and mould growth. This will make the feed unsafe and causes economic loss. Moisture plays a critical role in the storage of feed. The moisture content in the feed should be below 10%. Higher moisture content invites fungal growth which makes the feed stale and musty. Some of the species of fungi (Aspergellus flavus) contaminate the feed with aflatoxin which is poisonous to the animals. Absorption of moisture by the feed, in places where the relative humidity is very high, can be prevented by storing in air-tight containers. Eventhough, potassium metabisulphite (KMS), Sorbic acid, benzoic acid and propionic acid are used in many food stuffs to prevent mould growth, their use in the prawn feed needs to be investigated.

The use of certain growth promoting agents, such as anabolic steroids, hormones, and some antibiotics in the feeds of land animals, especially poultry, is well known. As such there are 'starter' and 'booster' feeds available for poultry farming. Investigations on the possible use of growth promoting agents in the feeds of prawns are very few. Encouraging results were not observed on the use of antibiotics (oxytetracycline) in prawn diets (Corliss et al., 1977; Vaitheeswaran and Ahamad Ali, 1986). It is reported that testosterone, glucosamine, prawn shell, and alfalfa extract had growth promoting effect (Rao et al., 1983; Vaitheeswaran and Ahamad Ali, 1986) in P. indicus. On the other hand thyroid and ethylostrenol (Oestrogen derivative) have no such effect. This is an areawhere work needs to be carried out. Invention of legally acceptable growth promoting substances may go a long way in achieving faster growth of prawns and increasing the efficiency of the feed.

The concept of Linear Programming (LP), in which the nutritionist first lays down a set of constraints and then lists all available rawmaterials which he wishes to be considered for selection by the computer to achieve the objective of least cost feed formula that will satisfy all the constraints, had been introduced in the animal feed industry some time ago. Its application in finding least cost feed formula for live-stock and poultry has gained widespread acceptance in most countries of the world. Recently LP in the least cost feed formulation for finfish (fresh water) has been attempted. This is a promising area in which the Linear programming techniques have to be introduced in the formulation of prawn feeds. For this purpose, the existing gaps in the knowledge of prawn nutrition need to be completely filled up. Data on the digestibility of common feed stuffs by the cultivable species of prawns, as in the case of present study, need to be obtained and documented, which will help in formulating cost-effective formula feeds for the large scale culture of prawns to augment their production.

TABLE - I. Some rawmaterials and their composition, used for compounding feeds.

Name of rawmaterial	Percent on dry basis				
	Crude protein	Fat/ lipid	Carbohydrate	Crude fibre	Ash
1	2	3	4	5	6
I. Energy feeds:					
Barley	9.9-20.29	2.17	16.34	5.81	2.36
Corn (Maize)	6.2- 9.6	4.3-5.5	69.6-70.7	1.4	1.4
Oats	12.0	2.4	63.7	5.0	--
Rice (whole)	8.4	2.1	76.7	0.7	0.8
Rice (broken)	7.5	0.5	79.9	0.3	0.5
Rice bran	13.24-15.80	18.2	47.43	9.0	14.8
Rye	11.6	1.7	69.8	1.9	2.0
Sorghum (Milo)	11.0	2.8	71.6	2.0	--
Tapioca	2.0	0.54	68.50	--	1.45
Wheat grain	13.07	1.96	63.61	3.91	3.85
Wheat flour	10.80	1.10	74.60	0.20	0.5
Wheat bran	13.90	4.20	55.60	10.50	5.3

TABLE - I (Continued)

1	2	3	4	5	6
II. Protein Supplements:					
(a) Plant materials.					
Brewer's grains	26.0	6.0	41.8	15.0	--
Coconut cake	25.96	11.2	22.19	--	8.88
Cottonseed cake	42.0	2.0	30.0	11.0	--
Distiller's grains	27.0	--	41.0	12.0	--
Gingelly cake	34.03	10.8	24.76	--	12.52
Gluten (Wheat)	25.0	2.0	48.0	8.0	--
Groundnut cake	48.42	7.56	28.18	--	6.03
Linseed	35.0	2.0	39.0	9.0	--
Malt sprouts	26.0	1.0	44.0	14.0	--
Rapeseed cake	46.0	1.0	28.0	14.0	--
Soybean cake	46.0	1.0	31.0	5.0	--
Sunflower cake	47.0	3.0	24.0	11.0	--

TABLE - I (Continued)

1	2	3	4	5	6
(b) <u>Animal materials</u>:					
Blood meal	80.0	2.0	--	--	0.52
Clam meat (*Sunneta scripta*)	48.10	13.55	16.69	--	7.62
Crab meal	30.0	1.7	--	--	--
Fish meal (Brownfish meal, low protein; white fish meal, high protein)	52-74	1.0-10.0	--	--	14.0-31
Mantis shrimp (*Squilla*)	44.06	7.55	1.27	--	23.63
Meat meal	53.0	10.0	--	--	12.03
Meat and bone meal	51.0	10.0	--	--	16.07
Mysid meal	76.05	2.72	5.57	--	15.66
Prawn waste meal	35.20	6.60	0.97	--	23.95
Silkworm pupa (i) whole	55.91-57.5	24.5-29.7	5.58	--	2.98
(ii) defated	75.36	1.75	8.40	--	5.59
Shrimp meal	36.0-48.0	3.0	--	--	--
Squid meal	81.38	9.63	5.33	--	3.66

TABLE - I (Continued)

1	2	3	4	5	6
III Non-conventional feed ingredeints					
House fly larvae	45.0	15.0	--	--	8.0
Poultry feather meal (Hydrolysed)	80-85	2.5	--	1.5	3.0
Single cell protein					
(i) Krill	55.0	10-15	--	--	15.2
(ii) Marine yeast	25.63	2.69	63.50	4.27	3.91
(iii) Petrolium yeast	61.22	2.10	26.24	3.9	6.54
(iv) Sludge	43.0	0.43	15.0	28.0	3.0
(v) *Spirulina*	60.89	9.0	6.63	--	13.0
Snail (Vivipara)	84.93	2.40	--	--	--
Worms:					
(i) *Limnodrilus*	47.21	24.15	--	--	--
(ii) Tubifex	64.48	16.0	15.40	--	0.9